Microturbines and Small Gas Turbines Technology: Progress and Challenges

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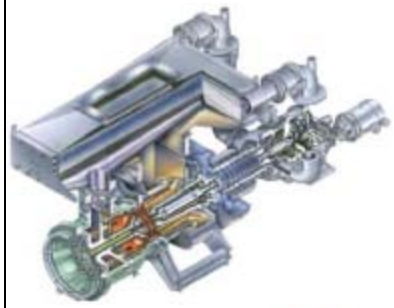
Agenda

- DOE Distributed Energy Program Overview
- Advances in Microturbine Technology
- Advances in Industrial Gas Turbine Technology
- Future Trends and Needs

DOE Distributed Energy Program Mission

The mission of the Distributed Energy (DE) Program is to strengthen America's energy infrastructure and provide utilities and consumers with a greater array of energy efficient technology choices for the onsite generation of electricity and use of thermal energy

Grid Support: Distributed Power Units Lower Manhattan, September 2001



Thermally activated technologies (chillers, desiccants)

Integrated Energy Systems (providing cooling, heating, electricity, dehumidification)

Prime Movers (industrial gas turbine, reciprocating engines, microturbines)

Levels of Integration

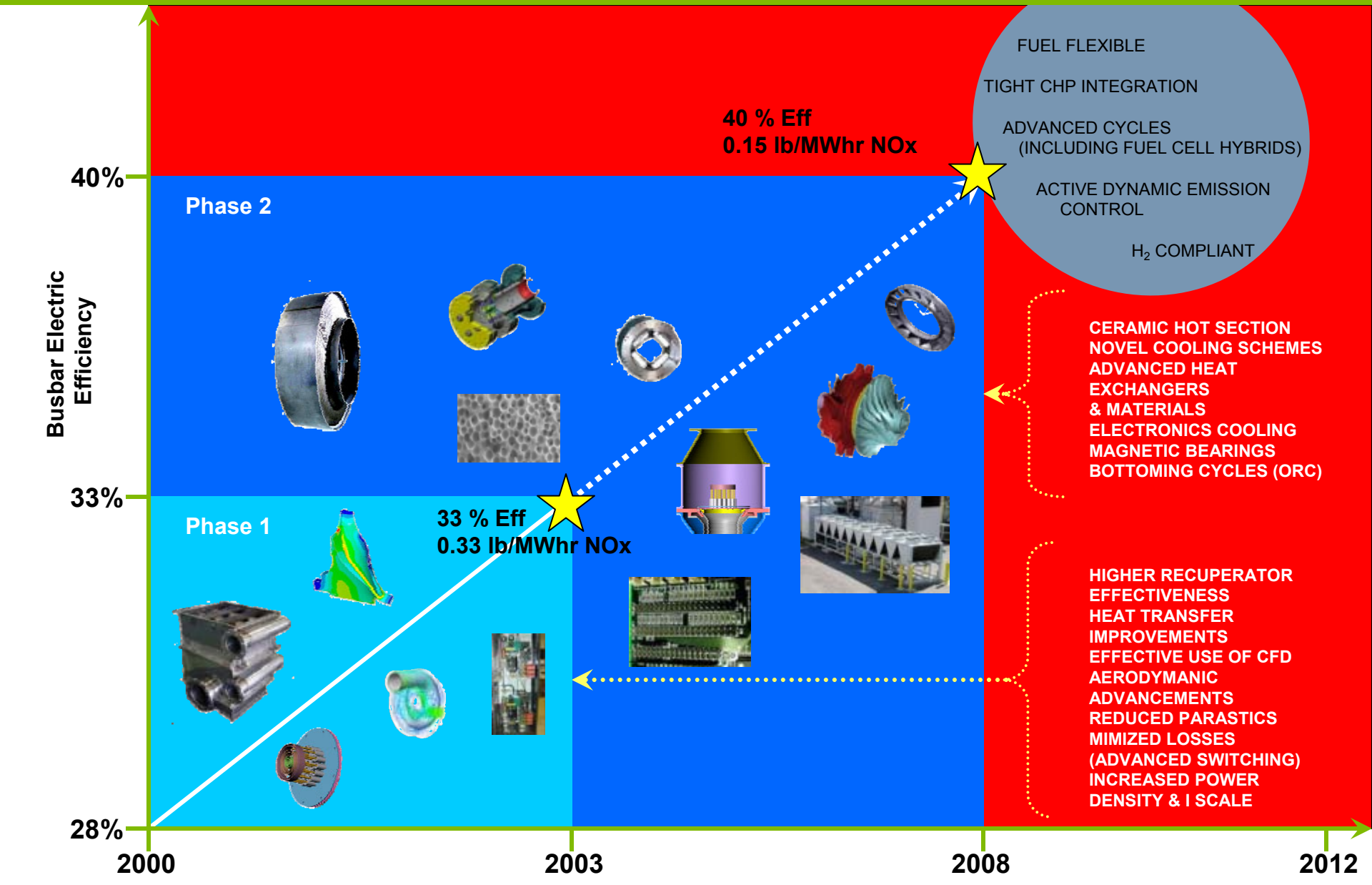
Increasing Levels of Integration

Equipment into Package CHP System

Package CHP System Into Building

Building-Integrated CHP into Community

Microturbine Program Goals



Capstone C200 Microturbine

- Shipped first beta unit to UCI for testing - 4/26/004
- 5,100 + Hrs of Operation
  - •95% Availability (excluding gas interruptions)
  - •Reported average performance: 207 kW with 33.5% efficiency

•Issues Discovered and Corrected:

- •Interior Ventilation Revised to Assure Proper Operation in Very Hot Weather
- •Power Electronics Capacitors Upgraded
- •Fuel Valve Electronics Repositioned for Better Air Flow

Integrated System Approach to 40%

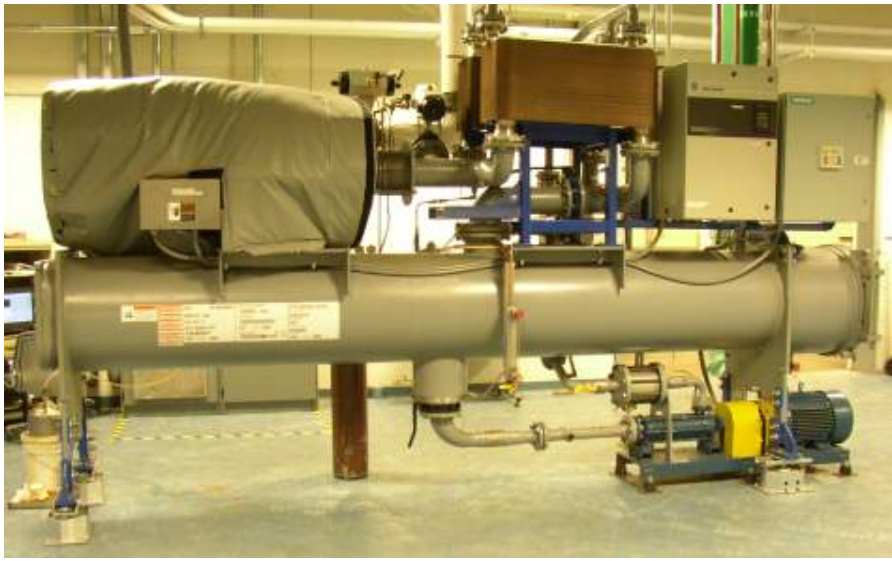
Two Capstone C200 + ORC

United Technologies Research Center

Integrate C200/ORC system

- Substitute water-cooled condenser
- Mechanical and control integration with C200
- Test integrated system

+



System Efficiency = $(P_{C200} + P_{ORC})/E_{fuel}$

= Eff_{C200} x $(P_{C200} + P_{ORC})/ P_{C200}$

= 33% x (400 +85)/400

= 40%

Integrated System Test Results

United Technologies Research Center

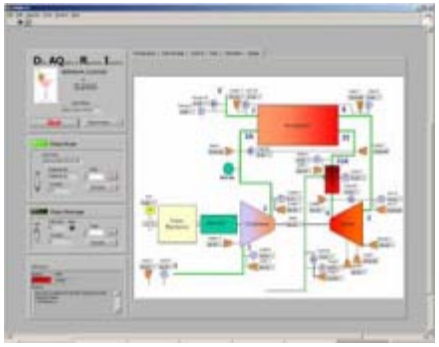
Integrated System Achieved 38% Electrical Efficiency

ORC power was low because of high cabinet cooling of C200 Beta design

Parameter		Integrated System			
		Spec	Meas	Spec	Meas
Ambient Temperature	F	34	34	34	34
C200 Beta Backpressure	in H_2O	0	0	4	4
C200 Beta Power	kW	400	400	400	400
C200 Beta Electrical Efficiency	%	32.6	33.1	32.3	32.8
PureCycle™ Power	kW	80.8	63.5	82.0	64.6
System Efficiency	%	39.2	38.4	38.9	38.0

GE Microturbine Update
May 2005

Open impeller motor tests to prove out rotor dynamic stability at speeds up to 30,500 RPM (67% speed)

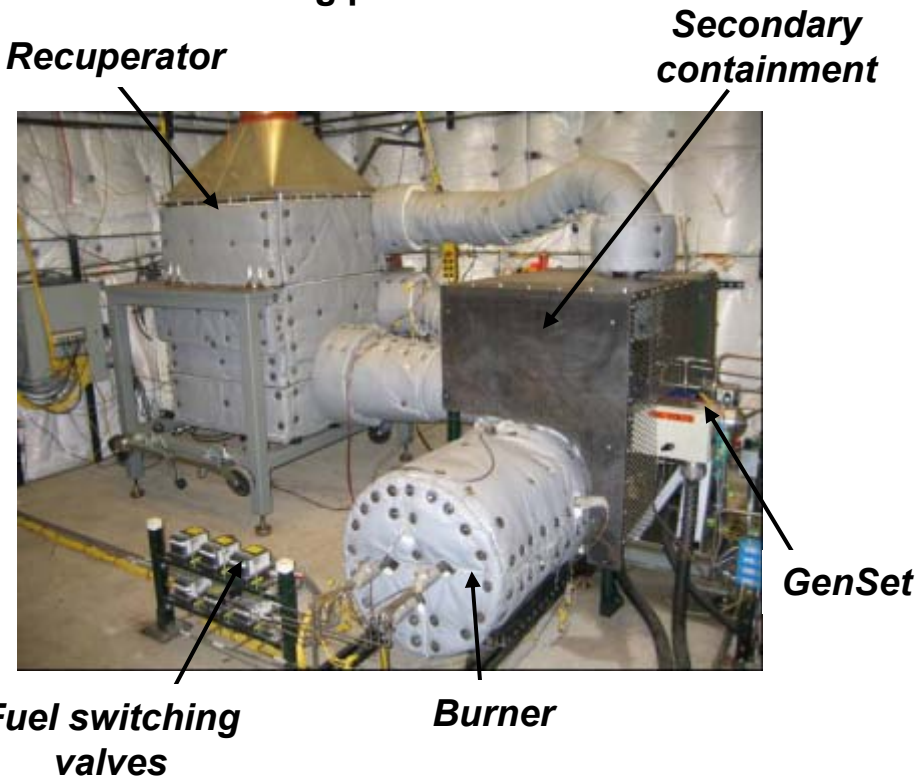


Data acquisition system on-line and recording performance data

May 05:
- Full system assembly complete
- Cold spin tests complete
- Rotor dynamic stability achieved

June-July 05:
- Combustor first fire
- Complete full speed-no load tests

Aug-Sep 05:
- Closed loop control operation
- Full speed-full load testing



Advanced Recuperator Materials Research

Maximum Materials Temperature Capability (˚C)

600˚C 650˚C 700˚C 750˚C 850˚C 950˚C

IR Bowman POWER The New Wave in Energy

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Capstone

347

Mod 347

20/25 Nb

United Technologies

Capstone

GE

Haynes 120

Special Metals 803

Haynes 230

Haynes 214

Candidate Materials are being evaluated in the Recuperator Test Facility

2000 2002 2004 2006 2008 2010 2012

TIME (y)

IR 250kW Microturbine

- Based on KG2 engine design (single shaft)
- 30% Efficiency (LHV)
- NOx < 9 ppm (<0.5 lb/MWh)
- 80,000 design life

- Integrated heat recovery
- Weatherproof outdoor enclosure
- Closed transitions to grid-isolated mode during grid outages

Microturbine Customer Solutions

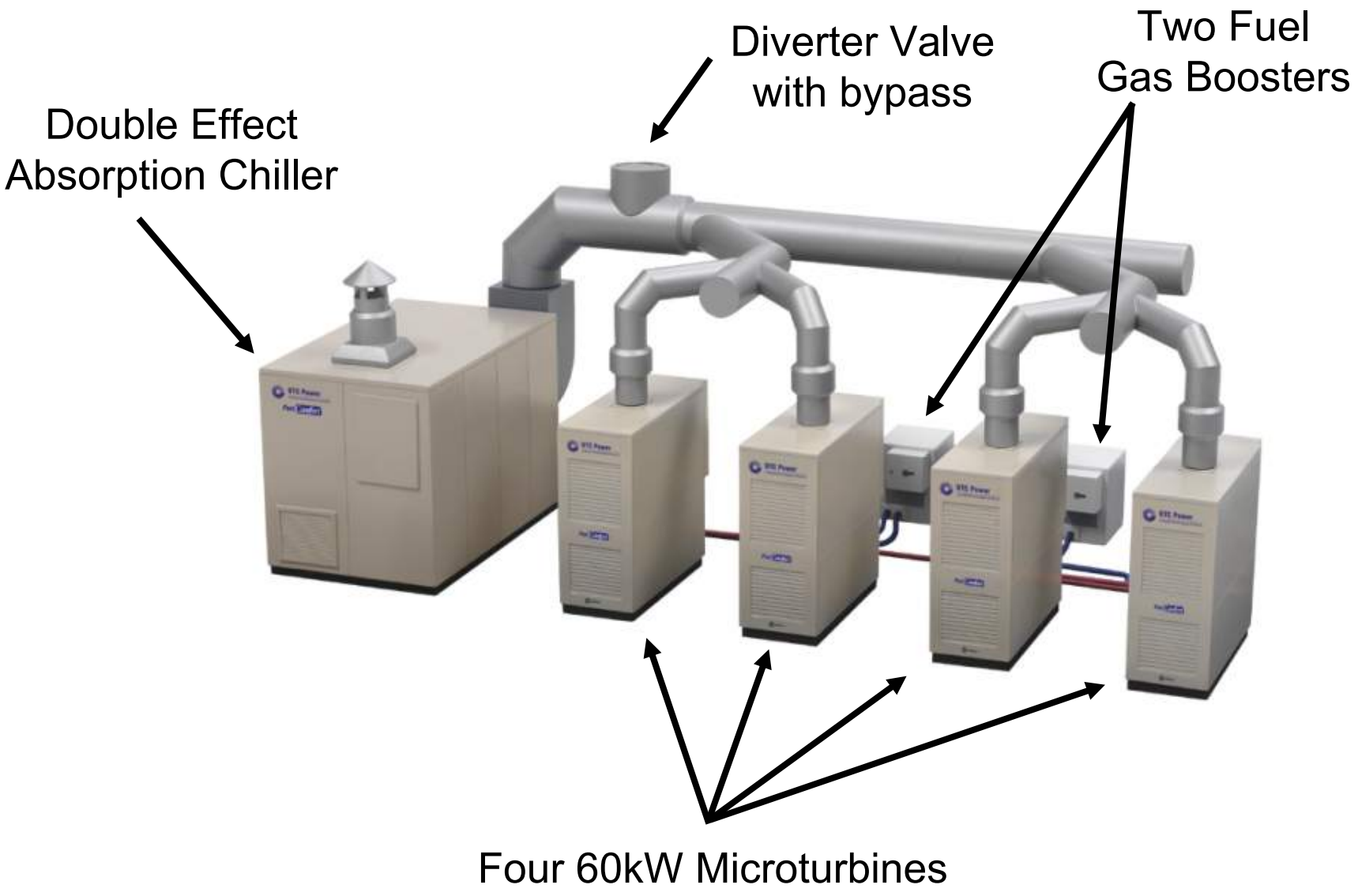
ELLIOTT ENERGY SYSTEMS
EBARA GROUP

1.5 MW Microturbine Installation

- Existing Boiler Housed in Building – Will remain as reserve.
- 33,000 Gal Hot Water Reservoir
- Pump Building
- Water flow path to and from Microturbines
- Bank of 15 TA100 CHP microturbines. Supply 100 kW Ea.

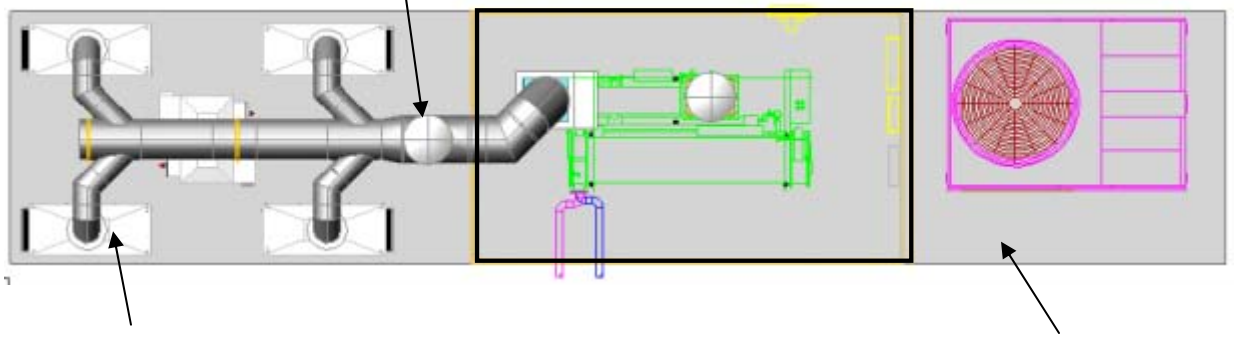
PureComfort™ 240M is a Packaged CHP System

229 kW net power and 161 RT on ISO day → 91% CHP



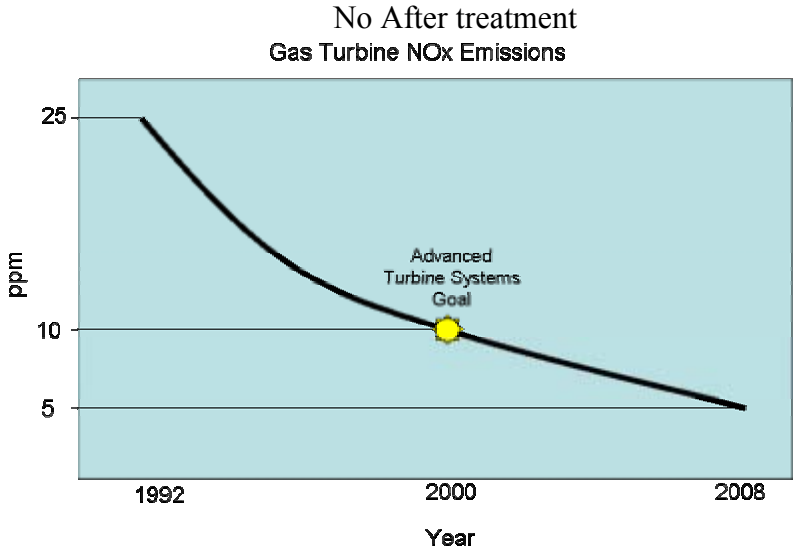
Skidded PureComfort™ 240M Installed at A&P

Ribbon-Cutting held May 17, 2005

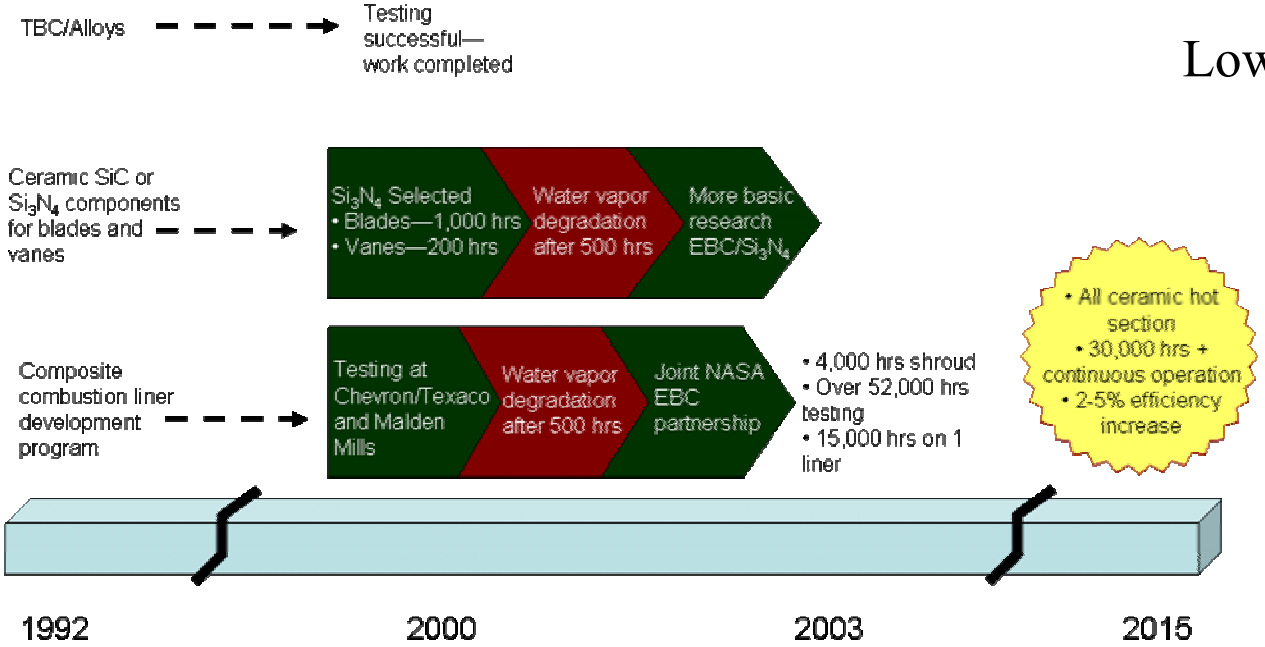


Industrial Gas Turbine Program

Completed field demonstration of 4.6MW advanced turbine system which produces onsite power with high efficiency and ultra low emissions without after treatment. Technology announced as commercially available in 2004



Low Emissions



Materials

Performance of Mercury 50

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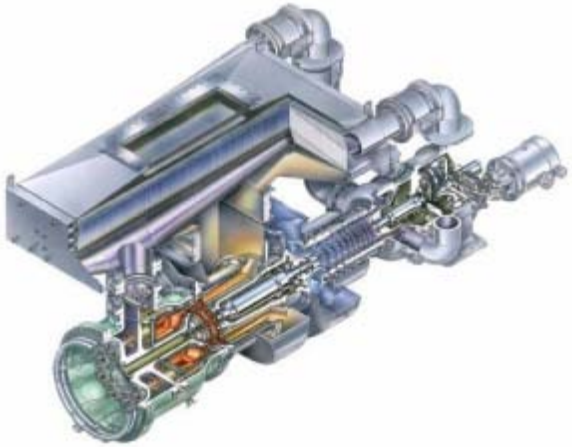

- 4600 kWe
- 38.5% Thermal Efficiency
- 8863 Btu/kW-hr (9343 KJ/Kw-hr)
- 705 F (374 C) Exhaust Temperature
- 5 ppmv NOx @ 15% 02 with
  Ultra Lean Premix Combustion

Mercury 50 Technology Features

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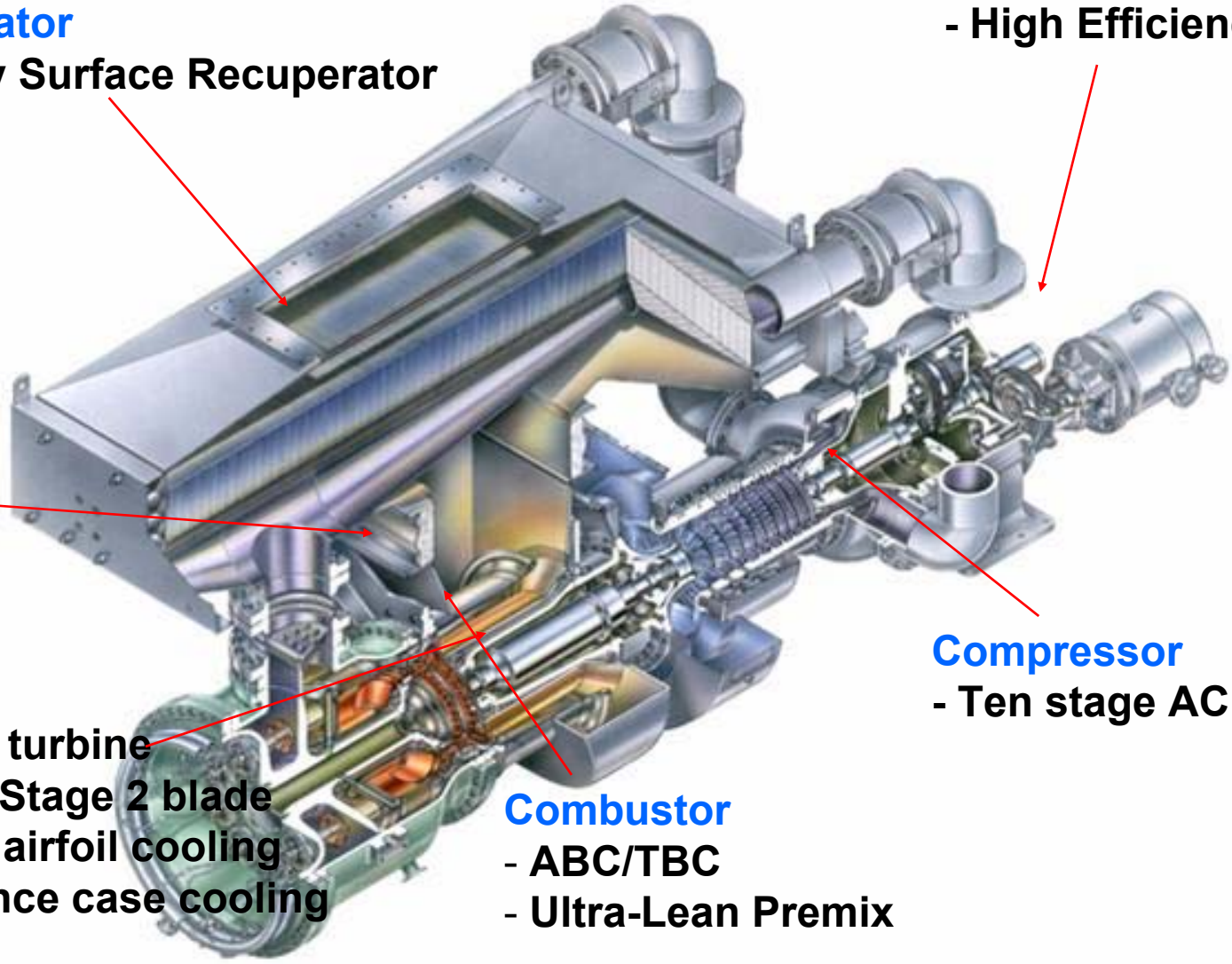
Recuperator
- Primary Surface Recuperator

Gearbox
- High Efficiency



Air Diverter Valve

Turbine
- Two stage turbine
- Shrouded Stage 2 blade
- Advanced airfoil cooling
- Tip clearance case cooling

Combustor
- ABC/TBC
- Ultra-Lean Premix

Compressor
- Ten stage ACE

Mercury 50 Production Sites

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Sempra/VA Hospital

- Start-up Nov 2004
- > 3500 operating hours

Qualcomm

- Installed April 2005
- Start-up July 2005
- CHP – continuous

Innovative NOx Solutions for Gas Turbines
Building Commercial Momentum

Catalytica ENERGY SYSTEMS

Xonon Cool Combustion

- Kawasaki GPB15X (1.4 MW)
  - >25,000 hours of engine operation at customer sites
    - NOx emissions consistently well below 3 ppm guarantee
    - Actual recorded emissions: 1 - 2 ppm NOx
  - Additional commercial installations under construction

Kawasaki Gas Turbines

GE Oil & Gas

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GE10

- Successfully completed full-scale engine tests in Q1 ’05
- NOx emissions < 1-ppm at base-load, and < 3 ppm over a range of operating conditions
- Next program milestone – field demonstration at a customer site

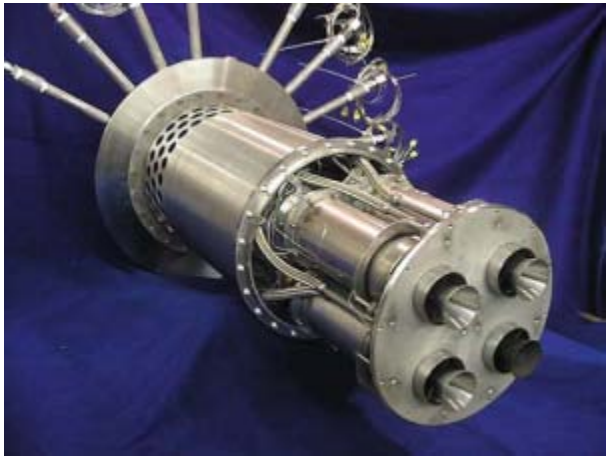
Taurus 70

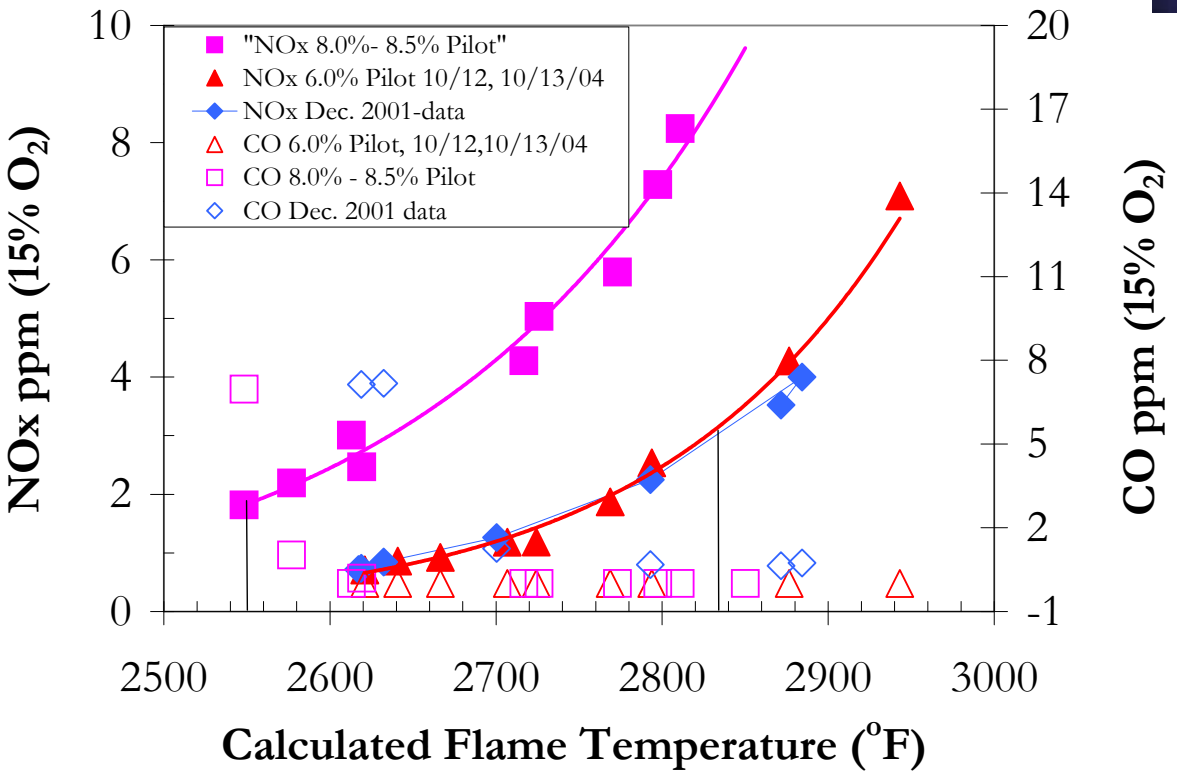
- Jointly funded by CEC
- Xonon combustion system based on CESI pre-burner and mixer design
- Successfully completed full-scale rig tests Q3 ‘04

PCI Low Emission Technology

PCI
Precision Combustion, Inc.

Tests of PCI's RCL (Rich Catalytic reactor/ Lean burn) technology were conducted at Solar Turbines on a Taurus 70 high pressure rig (with one RCL module) and on a Saturn engine (with four RCL modules)





- ***< 3 ppm NOx Emissions with very low CO demonstrated for a primary zone temperature range of 2550 to 2830F***

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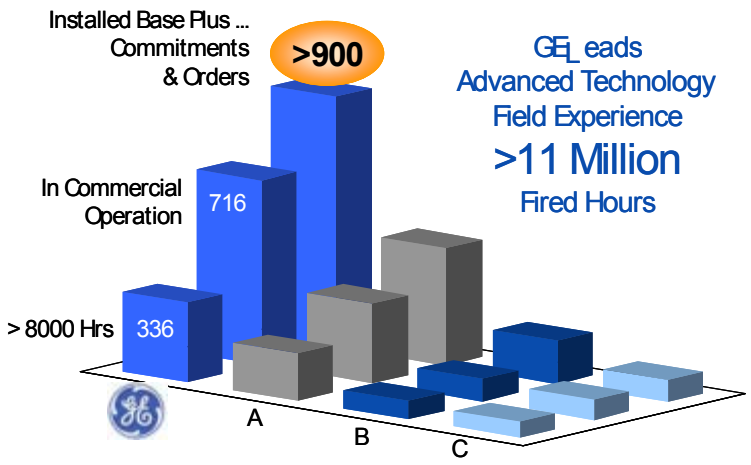
Payoff & Selected Applications for Ceramic Matrix Composite (CMC)

- **Higher temperature capability of CMCs allows reduction/elimination of air needed for cooling metallic components**
  - **Improvement in fuel efficiency**
  - **Reduction in harmful emissions**
  - **Higher output of machines**
- **Applicable to all classes of gas turbines**
  - **GE gas turbines range 45 KW to 280,000 KW**
  - **F-class & H-class machines most advanced**
  - **Installed base for F-class machines**



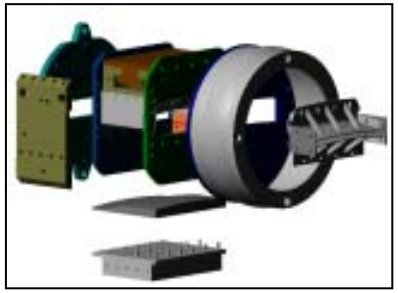
- **Current focus on shrouds & nozzles**
  - **Technology would flow to other stationary and rotating components**
  - **Early work on large combustors could not yet meet design to cost targets – working smaller combustor with Solar for feasibility demo**

Current Program focused on CMC applications in F-class machines

Development Path of CMC Shrouds

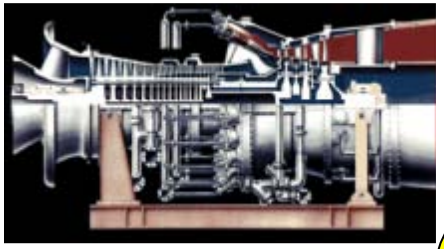
Stg. 1 Shroud

Stg. 2 Shroud



CMC Shroud Rig Test

7FA 160MW

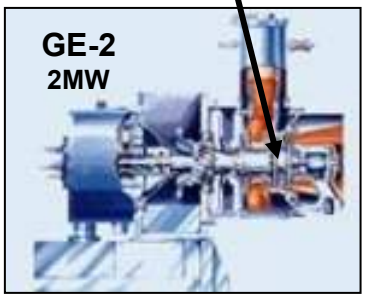


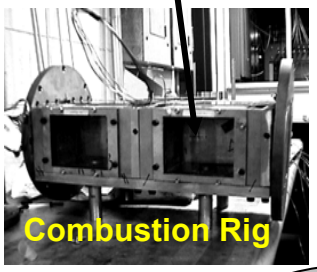
Engine Field Test (2005)

Rig Qualification Sealed Design (2005)

MI-CFCC

HS-188





Field Engine Validation Test 2002-2003

14 cycles & 5366 hrs

Rig Qualification Unsealed Design 2001-2002

50+ cycles & 300 total hours

Small Engine Testing 1999-2000

60 cycles & 1000+ hrs

Feasibility Rig Tests 1998

200+ cycles & 200 hrs

Material Development and Testing 1992-2002

Completed

In Progress & Future

Progressive "stepping stone" approach reduces development risk

imagination at work

Ceramic Composite Combustor Liners

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11 Field Installations

- DOE Ceramic Stationary Gas Turbine (CSGT) and Advanced Materials for Combustor programs
- May 2005: 70,000+ total hours of field testing
- ChevronTexaco Oil Exploration Site, Bakersfield, CA
  - **May 1997 - current**
  - **8 tests: ~ 40,000 hrs total test time**
  - **~15,000 hrs/79 starts longest test (oxide/oxide CMC)**

- Malden Mills Textile Plant, Lawrence, MA
  - **Aug. 1999 – July 2003**
  - **3 tests: 30,750 hrs total test time**
  - **15,144 hrs/92 starts longest test (SiC/SiC CMC)**

- Reduced emissions: NOx < 15 ppmv, CO < 10 ppmv

Integrated Gas Turbine CHP System

Achieving a system efficiency of 76% and higher

Burns and McDonnell Team

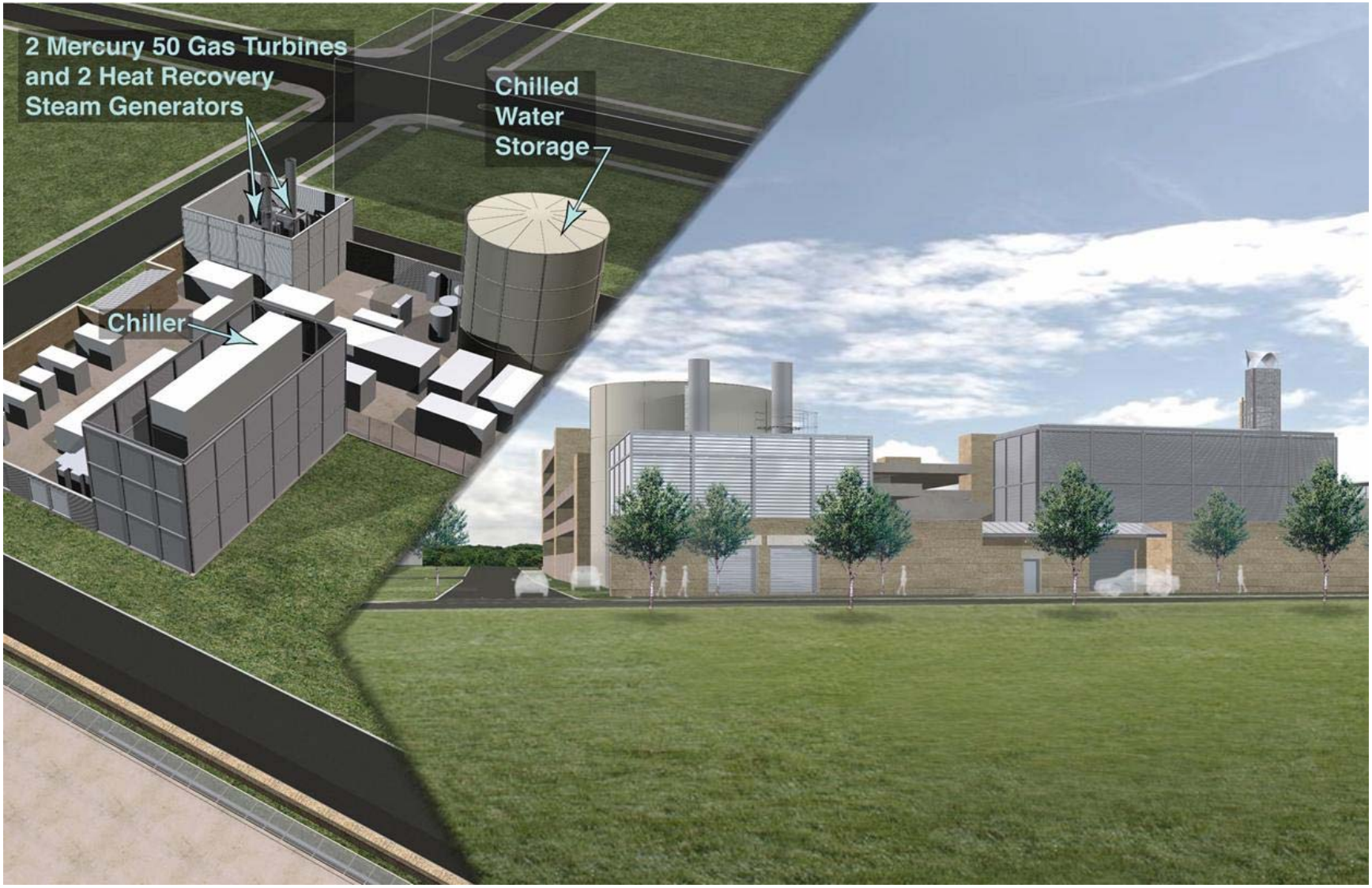
- 4.5 MW gas turbine integrated with 2,500 RT of waste-heat absorption cooling
- Mixed-use site with 1.2M-ft^2 office, retail, industrial and residential space with 15-MW base load
- Located in Austin TX at Domain High Tech Business Park
- Power can support utility grid

Honeywell Laboratories Team Improves Energy Security at Ft. Bragg

- 5.5 MW turbine integrated with 1,000 RT waste-heat chiller and HRSG
- Development of supervisory control systems with on-line optimization using real-time pricing
- Provision of reliable power to strategic command center & hospital

Ribbon Cutting Event:
June 2005

Mercury 50 Integrated CHP System Under Development



Summary

- Advances in Microturbines
  - Larger sizes: 200+kW
  - Increased efficiency – both prime mover and systems
  - Customer solutions – integrated Combined Heat and Power (CHP) systems
- Advances in Industrial Gas Turbines
  - High Efficiency and Low emission technologies
  - Use of Advanced Materials
  - Customer solutions – integrated Combined Heat and Power (CHP) systems

What's Ahead?

- Quest for higher Efficiency
  - Advanced cycles such as intercooled
  - Higher temperature with use of monolithic ceramics
- Low(er)? Emissions driven by Regulations
- Use of alternative fuels- greater adaptability
- Integrated Customer Solutions with enhanced feautures

For Additional Information:
www.eere.energy.gov/de

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